

Research Article

Classification and Quantification of Danmaku Interactions in Online Video Lectures: An Exploratory Study

Shugang Li,¹ He Zhu ,¹ Ying Qian ,² Shiqi Ren ,¹ and Bing Fang ¹

¹School of Management, Shanghai University, Shanghai 200444, China

²School of Management, University of Shanghai for Science and Technology, Shanghai 200093, China

Correspondence should be addressed to He Zhu; zhuhe201775@126.com

Received 4 January 2022; Revised 10 June 2022; Accepted 6 August 2022; Published 28 September 2022

Academic Editor: Kwok Tai Chui

Copyright © 2022 Shugang Li et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Danmaku is an important means of interaction in online education, providing a learning atmosphere of collaboration with peers. Nowadays, there have been more studies on Danmaku interaction. However, there are still some shortcomings in the existing literature for classifying and quantifying the content of Danmaku interactions. Semi-structured interviews were conducted with 35 informants to identify learner-content interaction that met learners' functional needs and learner-learner interactions that met social, hedonic, and emotional needs. Using content analysis of two video lectures, we found that learner-learner interaction accounted for one-third in both. More learner-content interaction occurred in the lecture with declarative knowledge (in which instructors encouraged learners to practice) than in the lecture with procedural knowledge (in which the learners followed fixed steps). Learner-instructor interaction was also identified—especially when instructors had specific personal characteristics. Learner-interface interaction was also evident—especially in lectures that had quality issues. Since the learner-instructor communication was only one-way (no response from instructors), it was not perceived by learners, indicating that learners' desire was not satisfied by Danmaku. The results of the study can provide teachers and content creators with advice related to course production and help teaching faculty recognize the importance of one-to-many interactive language and Danmaku interactions for learners.

1. Introduction

In China, a policy of “Internet + education” has been introduced to promote the development of online education. Given the advantages of high accessibility, added flexibility, and self-paced learning, the number of users of online education has increased exponentially, reaching 381 million, or 40.5% of all Internet users in China as of June 2020 [1]. The Chinese government supports the development of online education, and the 13th Five-Year Plan for the Development of National Education issued by the State Council in 2017 focused on the importance of the integration of information technology and education [2]. Online education is an important means of solving the problem of an imbalance in educational development and was also the best way for primary and middle school students to continue learning when their schools were closed during the Covid-19 pandemic.

The main form of online education is video lectures, which can be viewed whenever the learner chooses. This enables great flexibility at low cost and can reach huge numbers of learners. However, there are some issues in relation to video lectures, such as space-time separation, leading to inadequate interaction between learners and instructors. The space-time separation in video lectures results in a teaching process that is simply unidirectional information transmission from instructors to learners. Learners are forced to passively accept the knowledge transmitted in the video lectures and are prone to have feelings of boredom and monotony during the learning process, which eventually has a negative impact on their learning. Interaction is a basic feature of the education process [3]. It can even be said that the basic form of education is a process of interaction among instructors, learners, and educational content [4]. Thus, the lack of interaction in video lectures has constrained the development of the online education industry [5, 6].

The emergence of Danmaku technology has provided an opportunity for interaction in online education. Danmaku is a video comment feature in which overlaid comments flow across the screen from right to left. It is an unusual fluttered direction in China, because the Chinese language is written and read from left to right, but also because of this, it does not make it difficult for people to view the Danmaku. Unlike conventional comments that appear below the moving images, Danmaku is presented directly in video screen. The Danmaku sending time is associated with the time axis of the video lecture and is displayed as the video is played. Thus, Danmaku contents are more directly related to the video content and convey an impression of synchronicity. Many Chinese Web sites offer Danmaku features, among which <http://Bilibili.com> is very popular among young people. As well as entertainment videos, <http://Bilibili.com> provides a large number of video lectures. Figure 1 is a screenshot from a video lecture in <http://Bilibili.com>. It shows a national university entrance examination English-language video lecture. As you can see, there are many Danmaku comments that appear on the video, and they differ by color and size. Users can control whether the Danmaku function is displayed or not, and allowing viewers to make their own contributions (Figure 1). To post Danmaku comments, it is necessary to become a registered member of <http://Bilibili.com>: without membership, viewers can watch the videos but not post comments.

With the increasing popularity of Danmaku technology in ACG, movies, TV, short videos, live shopping, and online education, the younger generation of users has accepted the existence and use of Danmaku technology, and coupled with the epidemic factor, home learning has made the younger generation of learners have also accepted Danmaku interactions in online education and are able to obtain more information and discussion exchanges with the help of Danmaku.

The application of Danmaku has greatly increased learners' interactions in online video lectures. Compared with other interactive methods such as comments or messages at the bottom of videos, Danmaku displays the viewers' comments directly on the video, thereby creating a co-viewing experience, which can enhance the learners' sense of presence and reduce feelings of loneliness [7]. Danmaku has the advantages of relevance and diversification [8], as can be seen from Figure 1. Existing studies have found that Danmaku can improve learners' performance [9, 10] and learning efficiency [11]. To explore the influence of Danmaku on the learning process and learning results, Yang et al. conducted a meta-analysis of 25 variables related to Danmaku, such as Danmaku type and video duration, and found that Danmaku had a significant impact on learning results [12]. Thus, Danmaku is an effective means of solving the problem of insufficient interaction in relation to online education and improving online education outcomes. However, few studies have conducted a deep investigation of the Danmaku interaction mechanism which is important for online education toward addressing spatiotemporal factors and issues related to insufficient interaction. Accordingly, we examined the nature of Danmaku interaction in online education from two perspectives. First, we aimed to identify

the types of interactions that occur in Danmaku from users' experience. Second, we attempted to quantify each type of interaction to further understand the nature of Danmaku interaction in online video lectures.

This paper is organized as follows. We survey previous relevant studies in Section 2. Section 3 covers our qualitative study of the types of Danmaku interaction using grounded theory; Section 4 presents our quantitative study of Danmaku data using content analysis. We compare and discuss the results of those two types of study in Section 5. Section 6 concludes the paper and provides practical implications based on our findings.

2. Theoretical Background

2.1. Research Related to User Interaction. By reviewing and sorting out relevant studies on interaction in the field of information technology, we found that interaction is a multidimensional concept, and scholars in the field of information technology have mostly started from the elements of interaction at this stage but have not yet formed a more authoritative consensus on its dimensional composition. Most of the multidimensional studies related to Danmaku interaction in the existing literature focus on the definition and classification criteria of interaction based on different perspectives, and subsequent studies have also used empirical analysis to quantitatively elaborate the degree of influence of different dimensions of interaction on users' emotional state or willingness.

A summary of relevant domestic and international research literature in the field of information technology with interaction as the independent variable is shown in Table 1.

2.2. Research Related to Interaction in Online Education. In contrast, scholars in the field of online education have studied the interaction relationship more deeply, and a more authoritative composition of the interaction dimension based on the interaction relationship has been formed in the field of distance education and online education research, and most scholars have explored the interaction relationship between the three parties involved in online education (teacher, learner, and learning content). The relevant literature is summarized in Table 2.

In the field of foreign distance education and online education, theories that are commonly accepted by researchers and classified according to interaction relations include Moore's interaction classification theory. Moore stated that "As a minimum, distance educators need to agree on the distinctions between three types of interaction, which I labelled learner-content interaction, learner-instructor interaction, and learner-learner interaction. To distinguish among these three types will have benefits conceptually, but will also do much to overcome the misunderstandings between educators who use different media" [29]. This classification has been widely recognized in the field of distance education and also used in relation to online education.

Learner-instructor interaction: This type of interaction occurs when instructors provide information to learners,

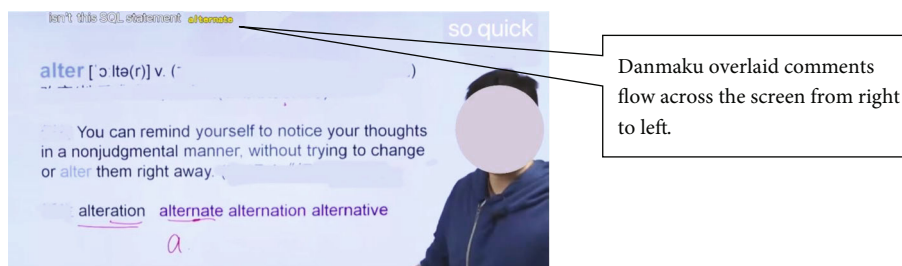


FIGURE 1: Danmaku in an online video lecture.

TABLE 1: Multidimensional study of interaction in the IT domain.

Dimensional composition	Research background	Author
Synchronous interaction, asynchronous interaction	Online communication	[13]
Perceptual control, perceptual response, perceptual personalization	Online sites	[14]
Active control, two-way communication, synchronicity	Online advertising	[15]
User control, gameplay, connectivity, responsiveness	Microblog	[16]
Interactive places, interactive features, interactive methods, interactive content	Virtual community	Fan, Ma. [17]
Perceived ease of use, perceived usefulness, perceived information exchange, perceived social interaction	Social networking sites	Ye. [18]
Perceptual convenience, perceptual personalization, sense of information exchange, social interaction perception	Danmaku videos	Li [19]
Time separation, focused immersion, high enjoyment, control, curiosity	Internet	[20]
Synchronicity, responsiveness, decentralization, and frequency of interaction	Live video	Fan [21]
Ease of use, usefulness, bi-directionality, responsiveness, and mutual assistance	Online shopping	[22]
Perceived ease of use, perceived usefulness, perceived entertainment, perceived social interaction, perceived personalization	Danmaku videos	[23]
Perceived usefulness, perceived ease of use, virtualness, anonymity, mutuality, responsiveness	Virtual community	Liu. [24]

TABLE 2: Multidimensional study of interaction in online education.

Dimensional composition	Research background	Author
Personal interaction, social interaction	Online education	[13]
Individualized interaction, social interaction	Online education	[25]
Personalized interaction (student-learning resource interaction). Social interaction (student-teacher interaction, student-student interaction).	Online education	[26]
Operational interaction (student-interface interaction). Information interaction (student-learning resource interaction, student-teacher interaction, student-student interaction). Conceptual interaction (interaction of old and new concepts for students).	Online education	[27]
Anchor-consumer interaction, consumer-consumer interaction	Live Danmaku	[28]
Teacher-student interaction, student-student interaction, student-learning content interaction	Online education	[29]
Academic, collaborative, and social interaction	Online education	[30]
Teacher-student interaction, student-student interaction, student-learning content interaction, student-interface interaction	Online education	[31]
Interaction between consumer and website, consumer and seller, interaction between consumers	Online shopping	Zhao, Wang, Zhou. [32]
Platform interactivity, anchor interactivity, interaction between consumers	Live Danmaku	[33]

participate in discussions, provide support and timely feedback, use multiple modes of communication, act as a role model, and encourage learners to participate [34]. Song et al. [35], using a questionnaire-based survey and path analysis, found that learner-instructor interaction can positively affect deep learning, which includes not only the deeper understanding and application of knowledge but also the level of the learners' concentration. Xu [36] used regression analysis to determine that learner-instructor interaction is positively correlated with online learning performance.

Learner-learner interaction occurs when learners share information with and obtain feedback from other learners. This form of collaboration among learners increases their engagement in the learning process [37]. A study of online education at 334 colleges and universities found that students benefit from the interaction between student groups and that such interaction has a positive impact on learning effect [38]. Another study reported that virtual learning community can increase learners' sense of belonging, leading to improved interaction between learners [39].

Learner-content interaction occurs between learners and the study content when learners are exposed to the course content and participate in classroom activities [29]. Here, course content mainly includes knowledge points and learning materials [40]. Chen et al. [38] found that a high level of interaction between students and learning content had a significant positive impact on online education outcomes. Thus, increased learner-content interaction helps to improve learning outcomes.

In the field of distance education, it has been found that learner-instructor interaction, learner-learner interaction, and learner-content interaction can improve online education outcomes. In this study, we applied Moore's interaction theory to explore the types of interaction that Danmaku can provide for learners.

2.3. Research Related to Danmaku Interaction in Online Education. The early use of Danmaku was related to ICT-supported learning in classrooms. Students watched a video and used Danmaku to share their opinions. Teachers monitored their questions and provided feedback either verbally or using Danmaku. At that time, research mainly focused on the control of the quality of Danmaku content, as well as the guiding and feedback functions offered by Danmaku in the teaching context [41]. It was found that Danmaku increased the opportunities for interaction between teachers and students and improved the teachers' ability to monitor the students' enthusiasm for learning [42]. However, it has also been reported that the Danmaku posted by instructors to guide the learning process increased the students' cognitive load [9].

More recently, Danmaku has increasingly been used in the development of online education [43]. Thus, researchers have started to investigate the effects of Danmaku in online learning. One study applied Danmaku to massive open online courses; it found that when comments and videos are displayed synchronously, it is easier to generate emotional resonance and promote real-time interaction [44]. One study used text mining to analyze Danmaku data

related to a Photoshop video lecture on <http://Bilibili.com>; it found that Danmaku helped to reduce the distance between instructors and learners, enhanced learners' social presence, and reduced feelings of loneliness in relation to online education [45]. It has been found that most students are willing to use Danmaku and hope that it is available while watching online video lectures. Having Danmaku enables learners to enjoy higher levels of social presence, learning satisfaction, and academic performance, while reducing their cognitive load [9].

Some studies have investigated Danmaku content. For example, Tong and Zhao [46] applied content analysis and found three reasons for using Danmaku, namely, information needs, entertainment needs, and social needs. Zheng et al. [47] used sentiment analysis of Danmaku content to identify users' emotional changes. Another study found that a combination of Danmaku and user comments made complementary knowledge sharing possible and promoted social interaction through online video lectures. Danmaku involves explicit knowledge sharing, while user comments involve more tacit knowledge sharing [45]. Chen et al. [48] analyzed the relationship between the timing of Danmaku posts and learning content in online video lectures. However, there remain many unanswered questions about Danmaku interaction in online education. The present study aimed to understand learners' perceived interactions from their personal experience through grounded theory and to analyze Danmaku interaction using content analysis.

In summary, low completion rates and high dropout rates are important factors limiting the continued development of online education [42], with insufficient interaction being the crux of online education development [49]. Danmaku interaction as an effective teaching and learning channel can alleviate student isolation and increase learners' motivation to learn.

Through the literature related to user interaction, learning interaction, and Danmaku interaction, it is easy to find that the current research on the role of interaction in online education and the factors influencing the willingness to continue learning have been studied to a certain extent; however, the existing research still has the following two shortcomings: (1) Content classification of Danmaku interaction in the online education field, lack of classification criteria, and lack of confirmation that Danmaku meets the needs of users. (2) The quantitative research on Danmaku interactions in online education is insufficient. Therefore, the subsequent research will use the rooting theory to realize the classification of perceived Danmaku interaction content and use content analysis to realize the quantitative research of Danmaku interaction classification.

3. Methodology of Grounded Theory to Identify Perceived Danmaku Interactions

Grounded theory, which was first put forward by Glaser and Strauss [50], is a qualitative research method that is used to investigate social actors and their relationships, interactions, and conflicts. It builds theory directly from field data. Therefore, it is suitable for analyzing perceived interactions using

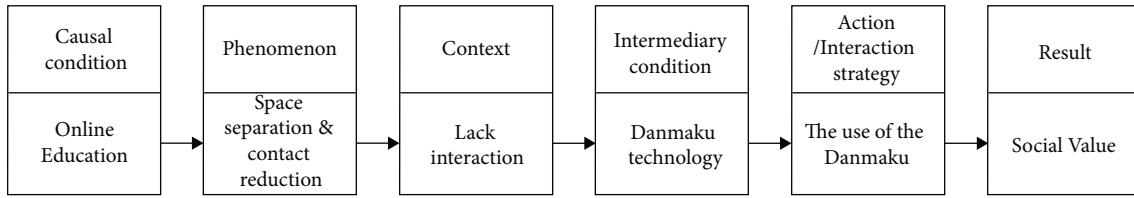


FIGURE 2: Sub-core category: social value.

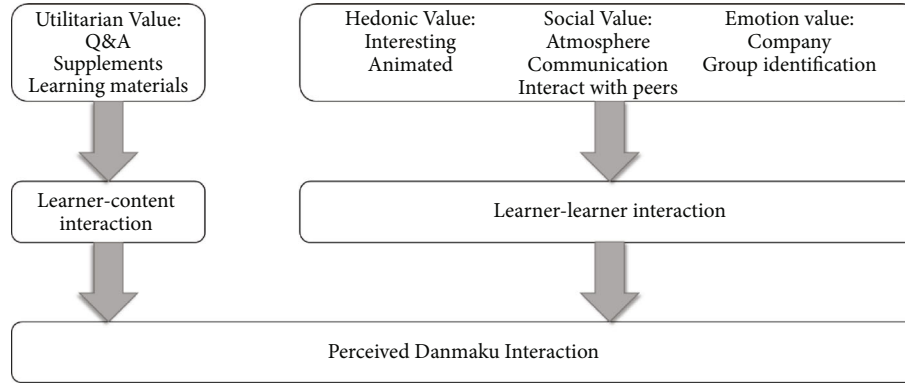


FIGURE 3: Perceived Danmaku interaction model.

Danmaku. Strauss and Corbin's procedural grounded theory includes three steps: open coding, axial coding, and selective coding [51].

3.1. Data. We selected a total of 35 students, all about 20 years of age, for interviews because the average age of Danmaku video website users is about 21 and most viewers of video lectures are students. The interviewees were assigned a number from 1 to 35 based on the time of interview. We retained five interviewees' audio files to enable us to conduct an interview saturation test. The interviews were semi-structured based on a guiding questionnaire, and were recorded and then converted to text using transcription software. The transcripts were checked and any necessary corrections were made.

3.2. Study Design. This study followed the steps of grounded theory: open coding, axial coding, and selective coding.

Open coding: The recorded file was stored with the sample code as the file name and then imported into NVivo 10 for open coding. Every sentence was conceptualized, and then the conceptualized data were categorized. We obtained 10 conceptual tags using open coding.

Axial coding: This is usually achieved by connecting the various categories obtained in open coding using the following canonical model: causal condition → phenomenon → context → intermediary condition → action/interaction strategy → result [52]. Figure 2 shows the process used to arrive at the sub-core category of social value. This step in the grounded theory process yielded four sub-core categories: social value, emotional value, hedonic value, and utilitarian value.

Selective coding: This is used to identify core categories through further abstraction and combination of the sub-core categories. By applying Moore's theory, we identified

the two core categories of Danmaku interaction: learner-learner interaction and learner-content interaction. Learner-learner interaction mainly reflects social value, emotional value, and hedonic value, while learner-content interaction reflects utilitarian value, as shown in Figure 3.

Theoretical saturation test: The five retained files were used as the data set to test for interview saturation. Following open coding of these five files, it was found that no new concepts or categories had emerged, indicating that the interviews had fully explored the factors influencing Danmaku interaction.

3.3. Results. Perceived Danmaku interaction in relation to online education includes learner-learner interaction and learner-content interaction, as shown in Figure 3.

Learner-learner interaction reflects the social value of Danmaku. Interviewees claimed that Danmaku provided a class-like atmosphere, as described by one interviewee: "I feel that there are many people watching this video with me" (a5). Learners were also able to communicate with each other: "Although we are not face-to-face, we can all exchange our views. That is, well, it feels like we are discussing and communicating with each other" (a6), and "our peers interact with us" (a7).

Emotional value also arises from learner-learner interaction. People can provide support for their peers and find company. As one interviewee noted, "What others said on Danmaku is the same as what I feel" (a2). Another stated, "First of all, it's like watching the video with someone else" (a1). Learners are free to express their feelings. As one interviewee stated, "Express my feelings, which is often the case."

Hedonic value is also derived from learner-learner interaction. Learners usually make jokes and share funny anecdotes. This was described as follows: "Sometimes, Danmaku is very funny, even funnier than the video" (a3),

and “It just feels like with Danmaku, the videos are better. It makes me feel a little bit more animated” (a4).

Learner-content interaction represents the utilitarian value of Danmaku and mainly includes questions and answers, supplementary details and summary points, early reminders of important knowledge points, and peers’ study progress. For example, various interviewees stated, “If I don’t understand what the teacher is talking about, then I’ll open the Danmaku to see if anyone has asked this question and an answer has been provided” (a8), “I may look at the Danmaku, because other people also have questions when they are learning, such as whether the title is wrong, or whether there are other solutions” (a9), “For example, if we don’t know some key points, there will be some people who have learnt this before, and they may explain it on Danmaku, so that I don’t have to search elsewhere” (a9), and “There will be some wonderful tips and early reminders of important knowledge points” (a10).

Furthermore, learners perceived that Danmaku was a way for them to remain aware of others’ learning progress, so that they could adjust their own schedule—especially when they were preparing for the same exam, such as the postgraduate admission examination: “I can see how other students are progressing and what they have done” (a11). Danmaku also revealed their peers’ thoughts and other information, as confirmed in comments such as “I can take a look at other people’s interesting points” (a11) and “It lets me see what other people think, and the difference between their thoughts and mine” (a11).

Using grounded theory, we identified two types of Danmaku interaction. The first was learner-learner interaction, which provides learners with social value, emotional value, and hedonic value. Interviewees mentioned that Danmaku created a class-like atmosphere and gave them the feeling of communicating with classmates, that is, a space-time interaction facilitated by quasi-synchronization. Discussion and communication between learners in Danmaku influenced the users’ sense of companionship and group identity, creating emotional value. The interesting and animated Danmaku that was mentioned by interviewees was generated through the process of dialogue with peers, which made the learning more enjoyable.

The second type of interaction was learner-content interaction, which influenced utilitarian value. Interviewees mentioned that Danmaku can answer their questions, provide supplementary details, and remind them of key points. Danmaku also contains the views of many other learners, thereby broadening the observation angle of the interviewee, expanding their knowledge beyond the learning content, and providing useful reference points. Furthermore, the interviewees mentioned that they were able to remain aware of other learners’ progress through Danmaku.

4. Methodology of Content Analysis to Quantify Danmaku Interaction

Content analysis is a widely used quantitative, systematic, objective method to study the characteristics of information. We applied this method to quantitatively investigate the user

interaction in Danmaku based on its content. We employed Moore’s interaction theory and the results from the above-grounded theory research for Danmaku coding in content analysis. Because the number of words in the Danmaku is small and the content is mostly colloquial, we choose content analysis method for manual classification, rather than text clustering and other methods, because these clustering methods require a certain length of text content and require formalization. The content analysis method can effectively improve the accuracy of the experimental results, although it puts forward higher requirements for researchers, who are required to have rich experience in the use of Danmaku and research experience. Our researchers fully meet these requirements.

4.1. Data. We selected two video lectures from <http://Bilibili.com> that had been viewed more than 20,000 times to study Danmaku interaction. <http://Bilibili.com> is the most popular Danmaku video website. In addition, the quality of the video lectures presented on <http://Bilibili.com> is steadily improving, and the Shanghai Municipal Education Commission designated <http://Bilibili.com> as one of its learning platforms during the Covid-19 pandemic [53]. Therefore, <http://Bilibili.com> has a unique advantage in that its video lectures provide a large amount of Danmaku text data.

We selected an English-language video lecture and a Photoshop tutorial video lecture, both of which were highly ranked in terms of broadcast volume. With the two video lectures, we chose the first episode.

In this paper, we used Python language to crawl Danmaku data: we collected 3639 Danmaku with 23,915 words for the English-language video lecture and 4348 Danmaku with 23,826 words for the Photoshop video lecture. We stored the Danmaku text of the video lectures as a .csv format file.

4.2. Study Design. The analysis was carried out on the basis of the recognized stages of content analysis.

First, we recruited six coders to do the coding work. They were all familiar with Danmaku and had been trained prior to undertaking the coding work [46, 54]. The training task contained about 100 Danmaku texts from the two sample video lectures. All of the coders were asked to code the Danmaku interaction based on a scheme that we developed in accordance with Moore’s theory and the results from the above study. During the training process, any inconsistencies and unclear instructions were resolved through group discussions. The scheme was refined and expanded through training and an iterative review of the Danmaku sample. The final coding scheme, including themes and descriptions, was as follows:

Learner-content interaction occurs in relation to information about knowledge points and learning materials.

Learner-learner interaction occurs when learners express their feelings, have fun, and chat about matters unrelated to the learning content; this was divided into subsets of emotional value, hedonic value, and social value.

Learner-instructor interaction occurs between learners and instructors.

TABLE 3: Coding of Danmaku interactions in online video lectures.

Danmaku interaction	English video lectures			Photoshop tutorial video lectures		
	Count	%	Sample	Count	%	Sample
Learner-learner interaction	Social value	260	9.54%	1280	29.44%	Hello, all 112 students. Thank you for your help!
	Hedonic value	533	19.57%	16	0.37%	2333333 6666666 Lalala.....
	Emotion value	122	4.48%	408	9.38%	What the ***?!
Learner-content interaction	1114	40.90%	The object is the receiver of the predicate action.	915	21.04%	Photoshop can also do frame by frame animation. It's PSCC!!
Learner-instructor interaction	271	9.94%	Teacher, you have made a mistake.	1640	37.72%	Send a friendly Danmaku to support the young lady.
Learner-interface interaction	424	15.57%	The voice is so small. I cannot understand what words without subtitles.	89	2.05%	Background music is Jay's Mojito.
Total	3639	100%		4348	100%	

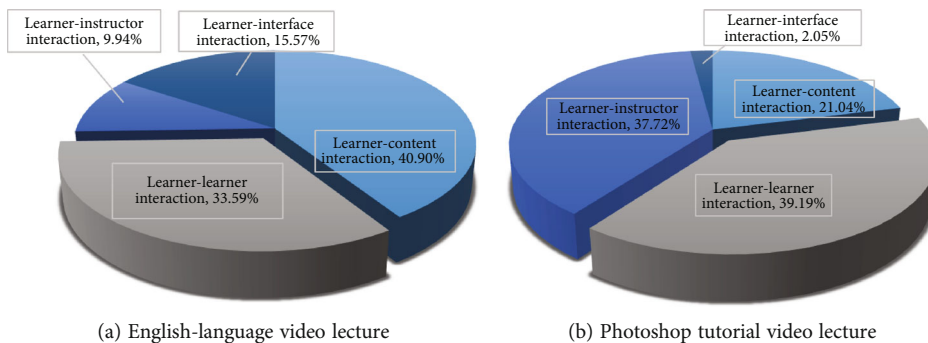


FIGURE 4: Shares of the four types of Danmaku interaction.

Learner-interface interaction was reflected in discussion about the videos themselves.

Then, using this coding scheme, the six coders were asked to code the Danmaku interaction independently. Each coder was assigned about 900 Danmaku texts.

When the coding work was complete, we checked the results by randomly selecting 100 Danmaku texts from each coder for recoding. The results were compared, and it was confirmed that more than 95% of the Danmaku texts were coded in the same category, indicating that the coding results were valid.

4.3. Results. The results of the Danmaku coding are presented in Table 3.

As shown in Table 3, there were four types of Danmaku interaction. The shares of each type of interaction are shown in Figure 4.

Learner-learner interaction is a major type of interaction in Danmaku, accounting for 33.59% of interaction in the English-language video lecture and 39.19% of interaction in the Photoshop tutorial video lecture. Learners like to use Danmaku for immediate interaction with their peers [55]. Three subtypes of learner-learner interaction were also identified: social value, hedonic value, and emotional value.

Social value was expressed in Danmaku comments such as “I’m in Henan province too,” and “I also know nothing!” Learners usually say hello to each other and try to identify any similarities among them. This accounted for 9.54% of interaction in the English-language video lecture, and 29.44% of interaction in the Photoshop tutorial video lecture.

Hedonic value expressed in Danmaku comments was usually in the form of network catchphrases. Catchphrases are linguistic memes created online to articulate common attitudes within a network community by means of particular phrases. For example, “666666” means “It’s fantastic!” “Lalalala” means “I’m so happy!” Hedonic value accounted for 19.57% of interaction in the English-language video lecture and 0.37% of interaction in the Photoshop tutorial video lecture.

Emotional value is expressed in comments such as “Come on!” “Go, go!” and “What the ***?!” Young learners often use Danmaku to express their feelings. Emotional value accounted for 4.48% of interaction in the English-language video lecture and 9.38% of interaction in the Photoshop tutorial video lecture.

Thus, the English-language video lecture had a higher hedonic value, while the Photoshop tutorial video lecture

had a higher social value. There are two reasons for this. First, the cognitive pressure in the two video lectures differs. In the Photoshop tutorial video lecture, learners are required to follow the instructor step by step, which means a higher level of concentration and cognitive pressure, leading to a low level of light-hearted Danmaku interaction. The cognitive pressure in relation to the English-language video lecture is relatively low, as the knowledge contained in it is declarative knowledge that needs to be learned through repeated exercises and memory after class, which led to more hedonic behavior during the English-language video lecture. Second, the instructor in the English-language video lecture was very humorous, and so learners felt relaxed and were more likely to respond lightheartedly on Danmaku.

Learner-content interaction is another major type of interaction in Danmaku and includes two main types of interaction: that related to knowledge points and that related to learning materials. For example, learners talked about the example proposed by the instructor in the English-language video lecture, namely, "The airplane is approaching Beijing," with comments such as "The object is the carrier of the predicate action." In the Photoshop video lecture, learners tended to ask, "How much is Photoshop?" "Photoshop 6?" (a version of the Photoshop software), and "Who has the electronic file of the textbook?" Learner-content interaction accounted for 40.90% of interaction in the English-language video lectures and 21.04% of interaction in the Photoshop tutorial video lecture. The English-language video lecture had more learner-content interaction because learners need to practice what they have learned to improve their performance, while the Photoshop tutorial video lecture mainly required the learners to follow the lecturer's instructions. The process is relatively fixed, and thus the learners do not need to discuss the steps. Therefore, learner-content interaction in the Photoshop tutorial video lecture mainly involved discussion about learning materials, such as the version of Photoshop.

Learner-instructor interaction was also identified in Danmaku content. Learner-instructor interaction mainly includes learners' comments to instructors, both supporting the instructors and asking questions. Learner-instructor interaction accounted for 9.94% of interaction in the English-language video lecture and 37.72% of interaction in the Photoshop tutorial video lecture. There were two reasons why there was more learner-instructor interaction during the Photoshop tutorial video lecture. First, to learn Photoshop, learners needed to follow the lecturer's instructions closely, and some had questions during the process, such as "Teacher, is this a sequence frame?" Second, the instructor presenting the Photoshop video lecture had created and uploaded the video herself. She was an inexperienced instructor but had a nice voice, and numerous learners expressed their support and encouragement using Danmaku, encouraging her to make more video lectures. For example, some of their comments included "Good voice," "You sound like that actress," and "I like your video, you should do more." In contrast, the English-language video lecture was one of a series of episodes that came from an external source, and there was little need to provide encouragement to the instructor.

Learner-interface interaction was reflected in the learners' comments about the video lecture, such as "The background music is Jay's Malt Sugar" and "The picture quality is pretty good." Learner-interface interaction accounted for 15.57% of interaction in the English-language video lecture and 2.05% of interaction in the Photoshop tutorial video lecture. The main reason why there was more learner-interface interaction in relation to the English-language video lecture was because the volume was relatively low, and students could not hear clearly; thus, many learners posted Danmaku comments such as "I feel the sound is low" and "Am I the only one who cannot hear the teacher clearly?" If there are any technical issues with a video lecture, such as low volume or blurred images, learners will complain in Danmaku, but if the video quality is good, they will tend not to comment; accordingly, in the Photoshop tutorial video lectures, that kind of interaction was relatively low.

5. Discussion

On the basis of Moore's theory, and using grounded theory and content analysis, we qualitatively and quantitatively investigated Danmaku interaction in online video lectures.

Learner-learner interaction is a key type of interaction facilitated by Danmaku. From the learners' perspective, learner-learner interaction plays an important role in the Danmaku interaction, providing learners with social value, hedonic value, and emotional value. This type of interaction greatly reduces the learners' feelings of loneliness and creates an atmosphere of classroom communication.

From a content analysis of the sample Danmaku data, we found that learner-learner interaction accounted for around one-third of all Danmaku interaction, indicating that Danmaku is an effective channel for learner-learner interaction. We also found that the instructor's personality affected learner-learner interaction. If the instructor is entertaining, this helps to create a relaxed atmosphere in which learner-learner interaction provides greater hedonic value. However, the level of complexity of the knowledge being presented and the associated cognitive pressure also affected learner-learner interaction. If the material being presented is difficult to understand, less hedonic interaction will occur.

Learner-content interaction is helpful for learners. Almost all of the interviewees commented that learner-content interaction using Danmaku provided them with additional information that was very useful.

Content analysis revealed that learner-content interaction included two types of Danmaku comments, those related to learning content and those related to the learning materials. If the video lecture contained more declarative knowledge, such as English language that needed to be practiced both during and after class, there were more Danmaku comments related to knowledge points, not only on lecture notes but also regarding practice. Yang [56] noted that adding related information to learning content can help promote the maintenance of declarative knowledge. Conversely, there is less learner-content interaction in video lectures that mainly involves procedural knowledge. Learner-content interaction

in these types of video lectures is more related to the learning materials.

Learner-instructor interaction was identified in content analysis, but was not mentioned by the interviewees. We found that the instructor's personal characteristics had the greatest influence on learner-instructor interaction. The instructor who presented the Photoshop tutorial video lecture was young, lacked teaching experience, and was quite nervous, but her voice was pleasant, and she had created and uploaded the video herself. In such situations, learners tend to post more supportive Danmaku comments to offer praise and provide encouragement. Conversely, when video lectures originate from external sources and/or are presented by a professional instructor, learners are less motivated to interact with the instructor.

However, learner-instructor interaction was not mentioned by the interviewees. That was mainly because the learner-instructor interaction was unidirectional: the instructors did not respond to the learners' comments in Danmaku. It would in fact be possible for instructors to watch videos and answer questions raised by students. The Danmaku platform can also indicate instructors' responses in the comments using particular user names or fonts. Currently, the learners' desire to interact with the instructor is not satisfied by Danmaku. Therefore, the interviewees made no mention of learner-instructor interaction.

Learner-interface interaction was identified in content analysis, but was not mentioned by the interviewees. Learner-interface interaction mainly occurred in the English-language video lecture, which had a volume problem, leading many learners to post a Danmaku comment complaining that they could not hear clearly. When the video lecture is high quality, such as the Photoshop tutorial video lecture, there is less need to post Danmaku comments regarding the interface. This is a natural response, and most learners do not require any interaction with the interface. Therefore, the interviewees did not mention this type of interaction.

6. Conclusion and Implication

We investigated Danmaku interaction qualitatively from the users' perspective and quantitatively on the basis of an analysis of sample Danmaku content. The theoretical contribution of this study is an increased understanding of Danmaku interaction in relation to online video lectures. We found that Danmaku greatly facilitates learner-learner interaction, whereby learners exchange ideas, express their feelings, and provide entertainment. Learner-content interaction is also very helpful in providing utilitarian value to learners. However, Danmaku does not satisfy the learners' desire for learner-instructor interaction because the instructors are not responding to the learners using Danmaku.

On the basis of these findings, the following practical implications for online education are proposed. Instructors presenting online video lectures should respond to learners' Danmaku comments to satisfy the learners' desire for learner-instructor interaction. For example, they could answer frequently asked questions. If numerous learners are asking similar questions, this indicates areas that are dif-

ficult to learn or unclearly explained; it would be very helpful if the instructor could address such questions. Alternatively, to achieve better interaction, instructors could prepare practice exercises and examples, and then provide the learners time to interact using Danmaku. This should improve the learners' level of participation and learning performance.

From the learners' perspective, when they are having trouble understanding the knowledge points, they can ask for help using Danmaku. If either the instructor or their peers answer their questions, it will improve their learning performance. It is also possible for learners to share their different viewpoints on Danmaku and discuss them with their peers.

From the perspective of the video lecture platform, Danmaku enables them to receive feedback on any quality issues regarding their video lectures. Platform can use Danmaku to identify problems related to video lectures and thereby improve their quality. The Danmaku platform should also encourage instructors to interact with learners. Cause it is possible to differentiate instructors' Danmaku comments from those of learners by means of special fonts or positioning on the Danmaku screen. In that way, learners can easily distinguish instructors' responses, which could facilitate their learning process significantly.

In general, in this study, we exposed the differences between the perceived interaction of Danmaku in online video lectures and the real Danmaku contents data. Also, we identified and quantified the interaction types in the Danmaku contents in more scientific method. Moreover, we revealed the challenges faced by instructors, learners, and platform regarding interactions in online video lectures, and provide practical recommendations in different angles, such as platform supervision and improvement of response efficiency. Platform was also asked to provide instructors with more obvious Danmaku font so that instructors can communicate with learners through Danmaku. Learners will perceive more learner-instructor interaction in the future. We also encourage learners to focus on video contents and make more contributions on Danmaku to share their ideas and different opinions. In general, with good use of Danmaku, we can improve the interaction efficiency of students and create class atmosphere. And since interaction can improve users' satisfaction and even their online learning performance, the improvement of Danmaku participation will be the focus of future research.

6.1. Limitations and Future Research. Because of the shortage of researcher and equipment, we only consider <http://Bilibili.com> as our Danmaku platform and only 35 interviewees have been fully interviewed. But there are some similar platforms in China that contain many video lectures that we do not have enough time and energy to take them into consideration. Otherwise, primary and secondary schools also face insufficient interaction and space-time separation in online education. The interaction mechanism in it may or may not be similar to the university learners and adults who study spontaneously mentioned in this study. Cause students in primary and secondary schools are facing more academic pressure but with worse self-control. So, in the future, we can extend our studies to cover kindergarten

through twelfth grade areas and make a thorough comparison. Maybe even take the culture difference into consideration. Since the COVID-19, students all over the world are facing the same problems, insufficient interaction, and space-time separation in online education. And online classrooms and video lectures may also serve as a future student-learning trend. From the perspective of research methods, we can introduce more advanced neural network to cluster the Danmaku contents data in the future, which can reduce the complexity and time of manual processing. At the same time, sentiment analysis can be introduced to analyze and quantify the user's Danmaku language. In the research model, we can introduce the literature of distance education in similar research fields. For example, with the help of cognitive stress model, which factors will affect the user's interaction behavior, thus further affecting the user's participation and satisfaction. At the same time, the technology acceptance model is also something we can use for reference, because the user perception in the Danmaku content is also an important factor affecting the user participation behavior.

In the future, we can conduct further research in the following three aspects, specifically: first, the interaction tools in the future online education environment have strong scalability, along with the rapid development of information technology, the future of online education with the assistance of 5G technology will be able to create a more immersive and immersive learning and experience environment for users. At this stage, this paper only focuses on the interaction impact of pop-up text, and subsequent research can expand the research scope of interaction tools such as VR interaction and virtual teachers to conduct horizontal comparative research and expand the research scope of interaction in the field of online education and information technology. The second aspect is the scalability of the knowledge types of the research samples in the online education environment. In this study, only online video course courses such as programming class and language learning class were selected for feature mining of interaction behaviors, and more segmented related studies can be conducted subsequently. In addition, the huge amount of interaction information generated by learners in the courses can be stored and processed in the future by means of establishing a separate database, etc. Therefore, the storage of interaction text data needs to be considered while expanding the research sample. The third aspect is the scalability of the research method in the online education environment. This paper adopts the rooted theory approach and content analysis method in qualitative research. However, due to the huge number of learner interactions, subsequent studies can continue to extend the research methods, such as using deep learning and machine learning methods to achieve clustering and classification of interaction data, in order to be able to better understand learners' behaviors and better construct an explanatory framework for the meaning of their behaviors.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interests.

References

- [1] China Internet Network Information Center, "Statistical report on the development of Internet in China," 2020, http://www.gov.cn/xinwen/2020-09/29/content_5548176.htm.
- [2] State Council, "The 13th five-year plan for the development of national education," 2017, http://www.gov.cn/zhengce/content/2017-01/19/content_5161341.htm.
- [3] Y. X. Guo, "On the process attribute and process value of education," *Educational Research*, vol. 9, pp. 3–8, 2005.
- [4] Y. Hu and B. S. Yin, "A review of interaction classification in distance education," *Journal of Distance Education*, vol. 30, no. 6, pp. 100–109, 2012.
- [5] J. Dewey, *Democracy and Education [1916]*, Macmillan, New York, 2014.
- [6] Y. Zhao, J. Lei, B. Yan, and C. Lai, "What makes the difference? A practical analysis of research on the effectiveness of distance education," *Teachers College Record*, vol. 107, no. 8, pp. 1836–1884, 2005.
- [7] J. J. Zhang, Y. H. Yang, and X. An, "Enabling learning interaction through 'Danmaku' videos," *Distance Education in China*, vol. 11, 2017.
- [8] H. F. Li and W. Wang, "The Danmaku video: a new orientation about online video interactive learning," *Modern Educational Technology*, vol. 25, no. 6, pp. 12–17, 2015.
- [9] A. P. Qian, *The Influence of Danmaku in Online Teaching Video on Learners*, Central China Normal University, Wuhan, 2017.
- [10] T. Yi, *The Influence of Danmaku in Online Teaching Video on Different Types of Knowledge Learning*, Central China Normal University, Wuhan, 2018.
- [11] X. Rui and L. Tinan, "Research on the construction and practice of learning community based on bullet screen video," *Software Guide (Education Technology)*, vol. 14, no. 6, pp. 22–24, 2015.
- [12] J. M. Yang, C. C. Wu, Z. L. Pi, and H. P. Xie, "Facilitating learning or interfering learning: a meta-analysis of impact of Danmaku on learning," *Research on Audio-Visual Education*, vol. 40, no. 6, pp. 84–90+120, 2019.
- [13] A. W. Bates, "Interactivity as a criterion for media selection in distance education," *Never Too Far*, vol. 6, no. 16, pp. 5–9, 1990.
- [14] G. Wu, "Conceptualizing and measuring the perceived interactivity of websites," *Journal of Current Issues & Research in Advertising*, vol. 28, no. 1, pp. 87–104, 2006.
- [15] Y. Liu and L. J. Shrum, "What is interactivity and is it always such a good thing? Implications of definition, person, and situation for the influence of interactivity on advertising effectiveness," *Journal of Advertising*, vol. 31, no. 4, pp. 53–64, 2002.
- [16] L. Zhao and Y. Lu, "Enhancing perceived interactivity through network externalities: an empirical study on micro-blogging service satisfaction and continuance intention," *Decision Support Systems*, vol. 53, no. 4, pp. 825–834, 2012.
- [17] F. Xiaoping and M. Qingguo, "Research on the influence of virtual community-based online interaction on online

- purchase intention,” *Journal of Zhejiang University (Humanities and Social Sciences Edition)*, vol. 39, no. 5, pp. 149–157, 2009.
- [18] Y. Xiaoyin, *Research on the Influence of Interaction Perception and Experience Value on User Engagement Behavior of Social Networking Sites*, Huaqiao University, 2015.
- [19] L. Xuejiao, *Research on the Influence of Interaction Perception on the Continuous Engagement Intention of Danmaku Users*, Chongqing University of Technology and Industry, 2017.
- [20] R. Agarwal and E. Karahanna, “Time flies when you’re having fun: cognitive absorption and beliefs about information technology usage,” *MIS Quarterly*, vol. 24, no. 4, pp. 665–694, 2000.
- [21] F. Xiaojun, J. Xinyu, N. Rongrong, and D. Xuebing, “The impact of interactivity of mobile video broadcasting on the intention of continued use,” *Journal of System Management*, vol. 29, no. 2, pp. 294–307, 2020.
- [22] J.-G. Tang, *Study on the Influence of Interactivity on Trust and Purchase Behavior Tendency in B2C environment*, Fudan University, 2006.
- [23] O. Liu, *Research on users’ Willingness to Continue Watching Danmaku Videos Based on the Perspective of Interaction Perception*, South China University of Technology, 2019.
- [24] L. Huan, *Research on the Impact of Online Interaction on consumers’ Purchase Intention in Transactional Virtual Communities*, Zhejiang University, 2011.
- [25] A. W. Bates, “Interactivity as a criterion for media selection in distance education,” in *The Annual Conference of the Asian Association of Open Universities*, University Terbuka, Jakarta, Indonesia, 1990.
- [26] L. Chen, “Information interaction activities and student information interaction network in distance learning,” *China Distance Education*, vol. 9, pp. 15–19+78, 2004.
- [27] L. Chen, “Instructional interaction model and instructional interaction hierarchy tower for distance learning,” *China Distance Education*, vol. 5, pp. 24–28+78, 2004.
- [28] M. Li, *Exploring the Impact of Interactive Demonstrativeness on Live e-Commerce Consumer Engagement*, Dalian University of Technology, 2021.
- [29] M. G. Moore, “Editorial: Three types of interaction,” *The American Journal of Distance Education*, vol. 3, no. 2, pp. 1–7, 1989.
- [30] I. Jung, S. Choi, C. Lim, and J. Leem, “Effects of different types of interaction on learning achievement, satisfaction and participation in web-based instruction,” *Innovations in Education and Teaching International*, vol. 39, no. 2, pp. 153–162, 2002.
- [31] D. C. A. Hillman, D. J. Willis, and C. N. Gunawardena, “Learner-interface interaction in distance education: an extension of contemporary models and strategies for practitioners,” *American Journal of Distance Education*, vol. 8, no. 2, pp. 30–42, 1994.
- [32] Z. Hongxia, W. Xinhai, and Z. Baogang, “Research on online interaction and presence and consumer trust in B2C online shopping,” *Management Review*, vol. 27, no. 2, pp. 43–54, 2015.
- [33] M. Ming, *Research on the Factors Influencing Consumers’ Impulse Purchase Intention in the Context of e-Commerce Live Interaction*, Shandong University, 2021.
- [34] J. L. Shackelford and M. Maxwell, “Contribution of learner-instructor interaction to sense of community in graduate online education,” *Journal of Online Learning and Teaching*, vol. 8, no. 4, 2012.
- [35] J. Song, J. B. Feng, and K. C. Qu, “Research on the impact of teacher-student interaction on deep learning in online teaching,” *China Electronic Education*, vol. 11, pp. 60–66, 2020.
- [36] E. Q. Xu, “Empirical analysis of the interaction between teachers and students on the performance of online learning,” *Research on the Education of Computerization*, vol. 37, no. 9, pp. 61–68, 2016.
- [37] J. H. Sharp and J. B. Huett, “Importance of learner-learner interaction in distance education,” *Information Systems Education journal*, vol. 4, no. 4, 2005.
- [38] T. Chen, Y. X. Gong, and Y. Pu, “Exploring the meaning of socialization: college students’ online teaching interaction and its impact on learning outcomes: a survey based on 334 universities’ online teaching,” *Research in Higher Education*, vol. 41, no. 6, pp. 72–81, 2020.
- [39] C. H. Tu and M. McIsaac, “The relationship of social presence and interaction in online classes,” *The American Journal of Distance Education*, vol. 16, no. 3, pp. 131–150, 2002.
- [40] C. S. Zhang, “A literature review of distance/online interaction classifications,” *The Journal of Educational Science*, vol. 4, no. 1, 2004.
- [41] J. Li and X. M. Zhang, “Preliminary study on the application of Danmaku in online education,” *Journal of Fujian Radio & TV University*, vol. 1, pp. 5–7+31, 2015.
- [42] C. Zhang, “Research on the application of Danmaku technology in teaching Chinese as a foreign language,” *Asia Pacific Education*, vol. 24, pp. 129–131, 2016.
- [43] Y. Chen, Q. Gao, and P. L. P. Rau, “Understanding gratifications of watching Danmaku videos-videos with overlaid comments,” in *International Conference on Cross-Cultural Design*, P. Rau, Ed., vol. 9180 of Lecture Notes in Computer Science, , pp. 153–163, Springer, Cham, 2015.
- [44] H. Li and X. L. Zhang, “Research on the application of Danmaku video in MOOC learning,” *China Educational Informatization*, vol. 18, pp. 84–87, 2016.
- [45] Q. Wu, Y. Sang, S. Zhang, and Y. Huang, “Danmaku vs. forum comments: understanding user participation and knowledge sharing in online videos,” in *Proceedings of the 2018 ACM conference on supporting groupwork*, pp. 209–218, Sanibel Island, Florida, USA, 2018.
- [46] C. Tong and Y. X. Zhao, “Research on the motivation and behavior of bullet video website users based on content analysis,” *Library Forum*, vol. 39, no. 6, pp. 80–89, 2019.
- [47] Y. Y. Zheng, J. Xu, and Z. Xiao, “Application of emotion analysis and visualization method in network video barrage data analysis,” *Modern Library and Information Technology*, vol. 31, no. 11, pp. 82–90, 2015.
- [48] Y. J. Chen, L. K. Zhuo, and Y. M. Zhao, “The video Danmaku user interaction behavior research,” 2021, <http://kns.cnki.net/kcms/detail/44.1306.g2.20201123.1350.002.html>.
- [49] H. J. Wu, W. S. Ge, and J. H. He, “A study on the influence of teacher support on willingness to continue learning in MOOC courses - based on the perspectives of S-O-R and TAM,” *Modern Distance Education*, vol. 3, pp. 89–96, 2020.
- [50] B. G. Glaser and A. Strauss, “The discovery of grounded theory: strategies for qualitative research,” *Social Forces*, vol. 46, no. 4, 1967.
- [51] A. Strauss and J. Corbin, *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, Sage, Newbury Park, 1990.

- [52] A. Strauss and J. Corbin, *Introduction to qualitative research*, Taipei: Giant Current Book Company, 1997.
- [53] Shanghai Municipal Education Commission, "Online education for primary and middle school students has been launched across the city," 2020, http://edu.sh.gov.cn/web/xwzx/show_article.html?article_id=105352.
- [54] K. A. Neuendorf, *The Content Analysis Guidebook*, SAGE Publication, 2002.
- [55] Z. H. Duan, *Interactive Activity Mode and Mechanism of Different Learning Styles in Online Video Learning from the Perspective of Activity Theory*, Central China Normal University, 2018.
- [56] Y. D. Yang, "Teaching strategies of declarative knowledge and procedural knowledge," *Journal of Tianjin Normal University (Basic Education Edition)*, vol. 11, no. 3, pp. 18–21, 2010.